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PCT/SG 2005/000037

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It is hereby certified that annexed here to is a true copy of **Application, Provisional Specification & Drawings** of the patent application as filed and detailed below:-

Date of application	:	**15-04-2004**
Application No	:	**339/CHE/2004**
Applicants	:	**M/s. Matrixview Technologies (India) Private Limited, No.69, Mahalakshmi Koil Street, Kalakshetra Colony, Besant Nagar, Chennai – 600 090, India an Indian Company**

In witness there of
I have here unto set my hand

Dated this the 12th day of April 2005
22th day of Chaitra, 1926(Saka)

By Authority of
THE CONTROLLER GENERAL OF PATENTS, DESIGNS AND TRADE MARKS.

M. S. V

(M.S.VENKATARAMAN)
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1514

ORIGINAL

1539/CHE/2004

15 APR 2004

FORM 1

THE PATENTS ACT,1970
(39 OF 1970)
APPLICATION FOR GRANT OF A PATENT
(SEE SECTIONS 5(2),7,54 AND 135 AND RULE 39)

1. WE, MATRIXVIEW TECHNOLOGIES (INDIA) PRIVATE LIMITED, of NO. 69, MAHALAKSHMI KOIL STREET, KALAKSHETRA COLONY, BESANT NAGAR, CHENNAI -600090, INDIA
AN INDIAN COMPANY

2. hereby declare -

(a) that we are in possession of an invention titled "DECOMPRESSING COMPRESSED DATA"

(b) that the Provisional Specification relating to this invention is filed with this application.

(c) that there is no lawful ground of objection to the grant of a Patent to us.

3. We further declare that the inventors for the said invention is/are :

NAME (a)	ADDRESS (b)	NATIONALITY (c)
THIAGARAJAN ARVIND	H24/6, VAIGAI STREET, BESANT NAGAR, 600090 CHENNAI, TAMIL NADU, INDIA	INDIAN

4. That we are assignees of the inventor.

5. That our address for service in India is as follows:- D. P. AHUJA & CO., 53 Syed Amir Ali Avenue, Calcutta 700 019, West Bengal, India. TEL: (033)22819195, FAX: (033)24757524.

6. That to the best of our knowledge, information and belief the fact and matters stated herein are correct and that there is no lawful ground of objection to the grant of patent to us on this application.

7. Following are the attachments with the application:

(a) Provisional Specification (2 copies)
(b) Statement and Undertaking on Form 3 in duplicate
(c) Formal drawings (12 sheets) (Provisional) in duplicate
(d) Rs 3,000/- by cheque bearing No.906543 dated 13.04.2004 on ICICI BANK.

Contd...2

We request that a patent may be granted to us for the said invention.

Dated this 13th day of April, 2004.

(S.D. AHUJA)
OF D. P. AHUJA & CO
APPLICANTS' AGENT

To
The Controller of Patents,
The Patent Office,
Chennai

FORM 2

THE PATENTS ACT, 1970
(39 of 1970)

PROVISIONAL SPECIFICATION
(See Section 10)

TITLE

DECOMPRESSING COMPRESSED DATA

APPLICANT

MATRIXVIEW TECHNOLOGIES (INDIA) PRIVATE LIMITED,
of NO. 69, MAHALAKSHMI KOIL STREET, KALAKSHETRA COLONY,
BESANT NAGAR, CHENNAI -600090,
INDIA
AN INDIAN COMPANY

The following specification particularly describes the nature of the invention

Field of the Invention

The present invention relates to a method and system for decompression of compressed data and other highly correlated data streams.

Background of Invention

Image and data compression is of vital importance and has great significance in many practical applications. To choose between lossy compression and lossless compression depends primarily on the application.

Some applications require a perfectly lossless compression scheme so as to achieve zero errors in the automated analysis. This is particularly relevant when where an automatic analysis is performed on the image or data. Generally, Huffman coding and other source coding techniques are used to achieve lossless compression of image data.

In certain other applications, the human eye visually analyzes images. Since the human eye is insensitive to certain patterns in the images, such patterns are discarded from the original images so as to yield good compression of data. These schemes are termed as "visually lossless" compression schemes. This is not a perfectly reversible process as the de-compressed image data is different from the original image data. The degree of difference depends on the quality of compression, and the compression ratio. Compression schemes based on discrete cosine transforms (DCT) and Wavelet transforms followed by lossy quantization of data are typical examples of visually lossless scheme.

As a general rule, it is desirable to achieve the maximum compression ratio with zero, or minimal, possible loss in the quality of the image. At the same time, the complexity involved in the system and the power consumed by the image compression system are important parameters when it comes to a hardware-based implementation.

Usually, image compression is carried out in two steps. The first step is to use a pre-coding technique, which is normally based on signal transformations. The second

step would be to further compress the data values by standard source coding techniques such as, for example, Huffman and Lempel-Ziv schemes.

Most efficient compression techniques require a transformation. This is also known as pre-coding. The initial pre-coding step is the most critical and important operation in image compression. The complexity involved with DCT and Wavelet based transformations is quite high because of the large number of multiplications involved. This is illustrated in the following DCT equation:

$$DCT(i,j)=\frac{1}{\sqrt{2N}}C(i)C(j)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}f(x,y)\cos\left[\frac{(2x+1)i\pi}{2N}\right]\cos\left[\frac{(2y+1)j\pi}{2N}\right]$$

$$\text{where } C(x)=\frac{1}{\sqrt{2}} \text{ if } x=0, \text{ else } 1 \text{ if } x>0.$$

In addition to the large number of multiplications involved in carrying out the above DCT equation, there is also a zigzag rearrangement of the image data, which involves additional complexity. DCT transformation uses a mathematical algorithm to generate frequency representations of a block of video pixels. DCT is an invertible, discrete orthogonal transformation between time and frequency domain.

Transformation aids in increasing the efficiency of a second step, the entropy coder. At this stage, if the entropy coder produces good compression ratios, then the pre-coding should transform the data into a form suitable for the entropy coder. If the transformation is not efficient, then the entropy coder is becomes redundant. Thus, pre-coding is the most important stage of any image compression algorithm.

Another important property of any transformation is that it is reversible, to allow the reverse process to be applied at the decompression stage to obtain the original image. This transformation is extensively used in JPEG algorithms and their variants.

However, DCT suffers from several problems. Firstly, the complexity of the equation in terms of the number of multiplications and additions. In the 2D case, with an array of dimension N x N, the number of multiplications is in the order of $2N^3$ using a separable approach of computing 1D row and column DCTs. Specifically, for an 8 x 8 pixel array which is used in the JPEG family, 1024 multiplications and 896 additions are required. There have not been any significant improvements to reduce this computational overhead.

Even though the image data is an integer, their multiplication to cosine terms in the formula produces fractional numbers or real numbers because cosine values are fractional in nature until and unless they are integer multiples of Pi, which may not be the case. Since fractional numbers need infinite precision to store them exactly, they might produce errors in the reverse process, resulting in loss.

Another popular transformation is the wavelet transform. This is used, for example, in the JPEG2000 image compression standard. A mother wavelet is used to decompose the image data into frequency sub-bands, which in turn increases the redundancy in most of the sub-bands, thereby improving compression ratios. Used in their original form, the mother wavelets do not give integer-to-integer transformation but when used after a process called lifting, they come integer-to-integer transforms. This makes the entire process lossless but does not achieve a high compression ratio.

Color transformations also offer another compression technique. A commonly used color space is RGB. In RGB, every pixel is quantized by using a combination of Red, Green and Blue values. This format is popular among graphic designers, but is not ideal as a compression algorithm.

It is desirable to provide an image compression system which does not involve rigorous transforms, and complex calculations. It also has to be memory efficient and power efficient.

There are various image compression techniques presently available. A familiar few are JPEG, JPEG-LS, JPEG-2000, CALIC, FRACTAL and RLE.

JPEG compression is a trade-off between degree of compression, resultant image quality, and time required for compression/decompression. Blockiness results at high image compression ratios. It produces poor image quality when compressing text or images containing sharp edges or lines. Gibb's effect is the name given to this phenomenon - where disturbances/ripples may be seen at the margins of objects with sharp borders. It is not suitable for 2-bit black and white images. It is not resolution independent, and does not provide for scalability, where the image is displayed optimally depending on the resolution of the viewing device.

JPEG-LS does not provide support for scalability, error resilience or any such functionality. Blockiness still exist at higher compression ratios and it does not offer any particular support for error resilience, besides restart markers.

JPEG-2000 does not provide any truly substantial improvement in compression efficiency and is significantly more complex than JPEG, with the exception of JPEG-LS for lossless compression. The complexity involved in JPEG-2000 is higher for a lower enhancement in the compression ration and efficiency.

Although CALIC provides the best performance in lossless compression, it cannot be used for progressive image transmission as it implements a predictive-based algorithm that can work only in lossless/nearly-lossless mode. Complexity and computational cost are high.

All data compression techniques are based on the fundamental principle of Shannon's Information Theory. This theory states that there is a limit to the number of bits required to code a unique symbol, also known as entropy. This is given as the following equation:

$$H = - p_i \log_2 p_i$$

Where Pi is the probability of occurrence of the symbol. The implication of this equation is that if a symbol occurs frequently, then this symbol contributes to repetition and is designated a lower priority when compared to a symbol whose frequency of occurrence is less. This forms the basis for all the entropy coding or source coding schemes. A shorter codeword is given to more probable events. For example, the more frequently the symbol occurs, the shorter its codeword is. Most encoders allot a minimum of at least one bit per symbol.

Image data follows a Palladian distribution. This means that the occurrence of each symbol is equiprobable. Thus, all the symbols require almost the same number of bits which results in very low compression ratios.

Summary of the Invention

In a first preferred aspect, there is provided a method for decompressing compressed data, comprising:

run-length decoding the compressed data;

arithmetically decoding the compressed data;

reverse transforming the decoded data; and

rearranging the transformed decoded data into a lossless decompressed form.

The reverse transformation may be one dimensional including horizontal variant, vertical variant, or predict variant. The reverse transformation may be two dimensional such as a multidimensional variant.

The rearranging the transformed decoded data may comprise a reversible sort process and a last to first rearrangement.

The image data may be reverse transformed according to Discrete Cosine Transform (DCT), wavelet transform or color transform.

The compressed data may be image data. The image data may originate from a photo, drawing or video frame.

In another aspect, there is provided a system for decompressing compressed data, comprising:

a run-length decoder and an arithmetic decoder for decoding the compressed data;

a reverse transforming module to reverse transform the decoded data; and

a data rearranging module to rearrange the transformed decoded data into a lossless decompressed form.

To achieve high compression, the image data stream is transformed from an even probability distribution in the original image to a probability distribution that has fewer symbols with a high frequency of occurrence and the remaining symbols with a relatively low frequency. This results in a significant reduction in bits per symbol and enhances the compression ratios.

The human eye is more sensitive to luminance than to color. Thus, chrominance luminance and value format is ideal.

It is essential for a decompressed image to be identical to the original image. Once information has been discarded during compression it cannot be retrieved. Thus, if during compression information was discarded, decompression only provides an approximation of the original image.

The algorithm of the present invention does not employ approximations and is able to guarantee a perfect reconstruction of the lossless compressed image. The codification technique of the present invention is ideally suited for highly correlated data and digital images, as there is high accuracy requisition, and certain errors and distortions can affect the image quality.

The present invention maintains full fidelity of the original digital data during the process of compression and decompression in a perfectly lossless manner. This renders a high compression ratio as there is no prediction or quantization or approximation in the process.

The present invention is a perfectly reversible technique of compression. The logical transform ensures a lossless and on the fly decompression. The original image data is retrieved perfectly lossless. As the reversion algorithm of the present invention is also an integer-to-integer transformation, loss of data is eliminated. The retrieved image is visually and mathematically identical to the original image data.

Firstly, decompression involves a decoding process. A run length decoder follows the arithmetic decoding. The decoded data is then passed for reverse transformation and data rearrangement. The reverse transformation primarily has four variants: horizontal variant, vertical variant, predict variant and the multidimensional variant.

The horizontal variant, vertical variant, and predict variant are classified as being in the one dimensional category. The multidimensional variant is classified as being in the two dimensional category. The data rearranging comprises a reversible sort process and a last to first rearrangement.

The method may be used for an application selected from: medical image archiving, medical image transmission, database system, information technology, entertainment, communications applications, and wireless application, satellite imaging, remote sensing, and military applications.

Brief Description of the Drawings

In order that the invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only a preferred embodiment of the present invention, the description being with reference to the accompanying illustrative drawings in which:

Figure 1 illustrates the entire image compression system based on repetition coded compression on a hardware implementation;
Figure 2 is a sample grayscale image of a human brain, which is captured by magnetic resonance imaging ("MRI") to demonstrate the compression able to be achieved by repetition coded compression system;
Figure 3 is an enlarged image of a small region from Figure 2;
Figure 4 shows that the image of Figure 2 is made up of many pixels in grayscale;
Figure 5 shows a 36-pixel region within the sample MRI image of Figure 2;
Figure 6 shows the ASCII value equivalent of the image data values for the image of Figure 2;
Figure 7 shows the application of repetition coded compression along the horizontal direction in the image matrix;
Figure 8 shows the application of repetition coded compression along the vertical direction in the image matrix;
Figure 9 shows the combination of horizontal and vertical bit-planes by a binary addition operation;
Figure 10 shows the total memory required for the 36-pixel region before and after applying repetition coded compression;
Figure 11 shows the application of repetition coded compression to the entire image; and
Figure 12 shows the operational flow for the implementation of repetition coded compression.

Detailed Description of Preferred Embodiments

Image data is a highly correlated. This means that the adjacent data values in an image are repetitive in nature. Therefore, it is possible to achieve some compression out of this repetitive property of the image and then apply Huffman coding or other source coding schemes. Such a method would be very efficient.

In repetition coded compression ("RCC"), each element is compared with the previous element. If both of them are equal then a value of "1" is stored in a bit-plane. Otherwise a value of '0' is stored in the bit-plane. Only the difference value is stored in a matrix, instead of storing all the repeating values.

In a one-dimensional performance of the method, only one bit-plane is used to code the repetition in the horizontal direction.

But in a two-dimensional performance of the method, two bit-planes are used to code the repetitions in both the horizontal and the vertical directions. This is more efficient and gives a better compression ratio.

The compression system is based on a mathematical comparison of adjacent image data values. The comparison is performed between adjacent image data values in both the horizontal as well as vertical directions. The bit-planes formed as a result of the comparison in the horizontal and vertical directions are respectively combined by a binary addition method. After this the resultant bit-plane positions are called as RCC bit-planes. The zero values in the RCC bit-plane are stored for lossless reconstruction of the original image. For lossless reconstruction, they are the only values stored. The stored values correspond to the same locations in the original image matrix as zeros in the RCC bit-plane and are hereinafter called RCC data values. All the other image data values can be reconstructed by using the RCC data values, and the horizontal and vertical bit-planes.

Figure 1 illustrates the entire image compression system based on repetition coded compression on a hardware implementation. The analog image signals 12 are captured by the camera 10 and are converted into respective digital data 16 by a analog to digital converter 14. This digital data 16 is rearranged into a matrix of image data values by a reshaping block 18. The reshaped image matrix is stored in the embedded chip 20, which performs the entire repetition coded compression system. This therefore gives the compressed repetition coded compression data values 22 and also the bit-planes of data 24 for storage, archival and future retireval 26.

Figure 2 is a sample image of the human brain which is captured by magnetic resonance imaging (MRI). This sample image may be used to demonstrate the compression achieved by repetition coded compression. It is a grayscale image.

Figure 3 zooms a small region from the sample MRI image of the human brain. This zoomed region may also be used for demonstrating the repetition coded compression system.

Figure 4 shows that the image is made up of lot of pixels in grayscale.

Figure 5 shows a 36-pixel region within the sample MRI image of the human brain.

Figure 6 shows the ASCII value equivalents of the image data values which are originally used for data storage. Each value requires eight bits (1 byte) of data memory. Currently, the 36-pixel region requires about 288 bits or 36 bytes of data memory. That data could be compressed and stored with only 112 bits after repetition coded compression.

Figure 7 shows the application of repetition coded compression along the horizontal direction in the image matrix. This results in the horizontal bit-plane and also the horizontal values stored.

Figure 8 shows the application of repetition coded compression along the vertical direction in the image matrix. This result in the vertical bit-plane, and also the vertical values stored.

Figure 9 shows the combination of horizontal and vertical bit-planes by a binary addition operation. This results in only five zero values which correspond to the final values stored from the original image matrix.

Figure 10 shows the total memory required for the 36-pixel region before and after applying repetition coded compression. The original memory requirement was 288 bits. After applying repetition coded compression the memory required was 112 bits. This is a great amount of compression.

Figure 11 shows the application of repetition coded compression to the entire image. The size is compressed to 44,000 bits from the original 188,000 bits.

Figure 12 shows an implementation of repetition coded compression. The image matrix 1201 is transposed 1202, encoded along the horizontal 1203 and vertical 1204

directions and the respective bit-planes 1205, 1206 are derived. Further compression is achieved by combining the horizontal and vertical bit-planes 1203, 1204 by a binary addition operation. This results in the repetition coded compression bit-plane 1207, which is logically inverted 1208 and compared 1209 with the original image matrix 1201 to obtain the final repetition coded compression data values 1210. The repetition coded compression data values 1210, together with the horizontal and vertical 1206bit-planes are stored in a data memory 1211 for archival and future retrieval.

The coded data can be further compressed by Huffman coding. This compression of the image data is achieved using the repetition coded compression system. This system is fast as it does not make use of complex transform techniques. The method may be used for any type of image file. In the example given above, the system is applied only for grayscale images. It may be applied to color images.

The system of repetition coded compression of images may be applied to fields such as, for example, medical image archiving and transmission, database systems, information technology, entertainment, communications and wireless applications, satellite imaging, remote sensing, military applications.

The preferred embodiment of the present invention is based on a single mathematical operation and requires no multiplication for its implementation. This results in memory efficiency, power efficiency, and speed, in performing the compression. Because of the single mathematical operation involved, the system is reversible and lossless. This may be important for applications which demand zero loss. The compression ratios may be significantly higher than existing lossless compression schemes.

Applications

Repetition Coded Compression (RCC) can be used in applications for medical imaging, digital entertainment and document management. Each of these verticals requires RCC to be implemented in a unique way to deliver a robust and powerful end product.

RCC can be deployed in the following forms for commercialisation:

1) ASIC or FPGA chips
2) DSP or embedded systems

3) Standalone hardware boxes

4) Licensable software (as DLLs or OCX)

5) Software deliverables

Whilst there has been described in the foregoing description a preferred embodiment of the present invention, it will be understood by those skilled in the technology that many variations or modifications in details of design, constructions or operation may be made without departing from the present invention.

A method for decompressing compressed data, comprising:
run-length decoding the compressed data;
arithmetically decoding the compressed data;
reverse transforming the decoded data; and
rearranging the transformed decoded data into a lossless decompressed form.

The reverse transformation is one dimensional including a horizontal variant, a vertical variant, or a predict variant.

The reverse transformation is two dimensional such as a multidimensional variant.

The rearrangement of the transformed decoded data comprises a reversible sort process and a last to first rearrangement.

The compressed data is image data.

The image data originates from a photo, drawing or video frame.

The method is used for an application selected from the group consisting of: medical image archiving, medical image transmission, database system, information technology, entertainment, communications applications, and wireless application, satellite imaging, remote sensing.

A system for decompressing compressed data, comprising:
a run-length decoder and an arithmetic decoder for decoding the compressed data;
a reverse transforming module to reverse transform the decoded data; and

a data rearranging module to rearrange the transformed decoded data into a lossless decompressed form.

The reverse transformation is one dimensional including a horizontal variant, a vertical variant, or a predict variant.

The reverse transformation is two dimensional such as a multidimensional variant.

The rearrangement of the transformed decoded data comprises a reversible sort process and a last to first rearrangement.

The compressed data is image data.

The image data originates from a photo, drawing or video frame.

Dated this 13th day of April, 2004

(S.D. AHUJA)
of D.P. AHUJA & CO.
APPLICANTS' AGENT

MATRIXVIEW TECHNOLOGIES (INDIA) PRIVATE LIMITED 12 SHEETS

NO. 339 /CHE/2004 SHEET 1

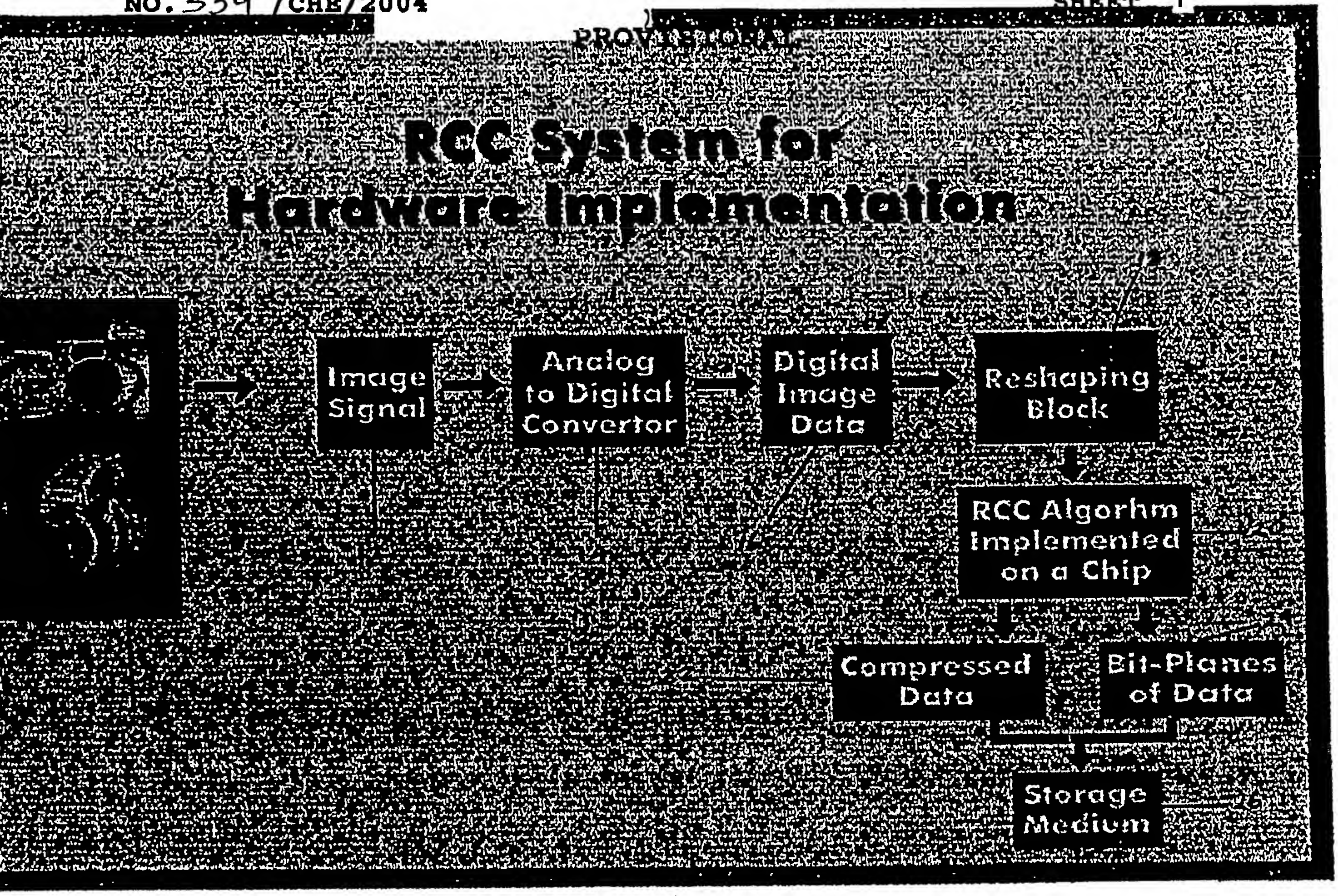

Figure 1

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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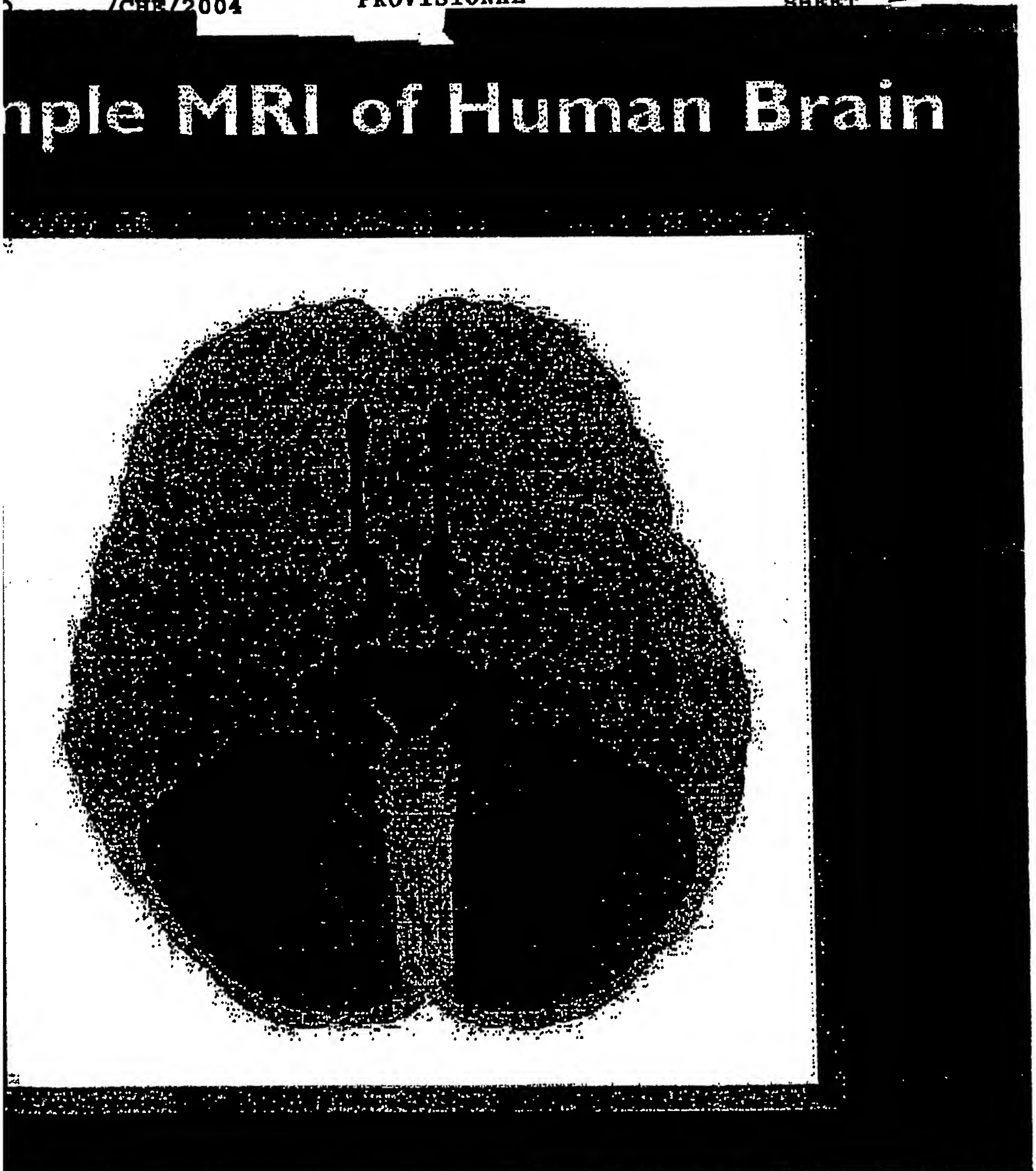

Figure 2

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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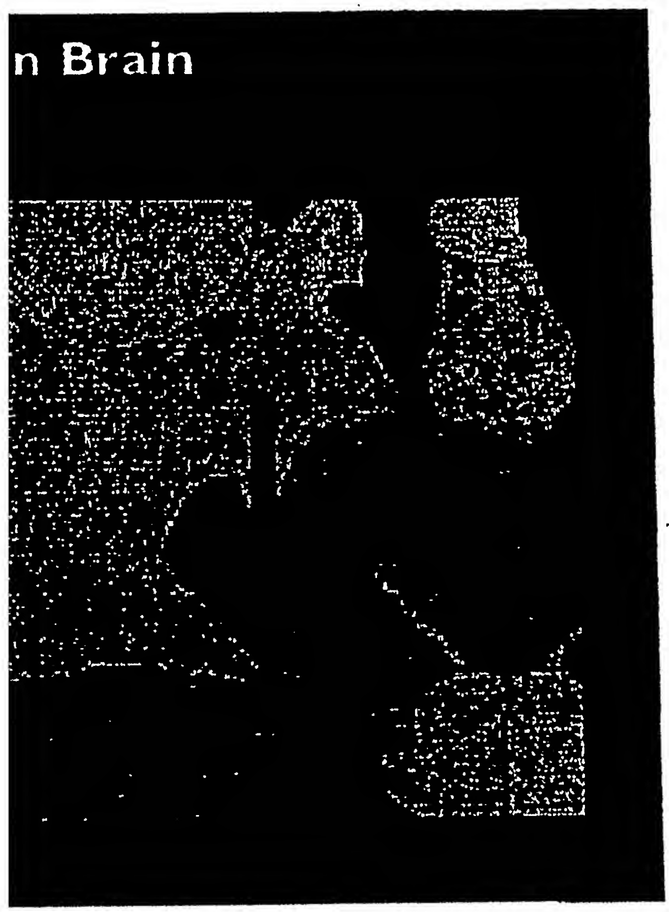

Figure 3

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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AL

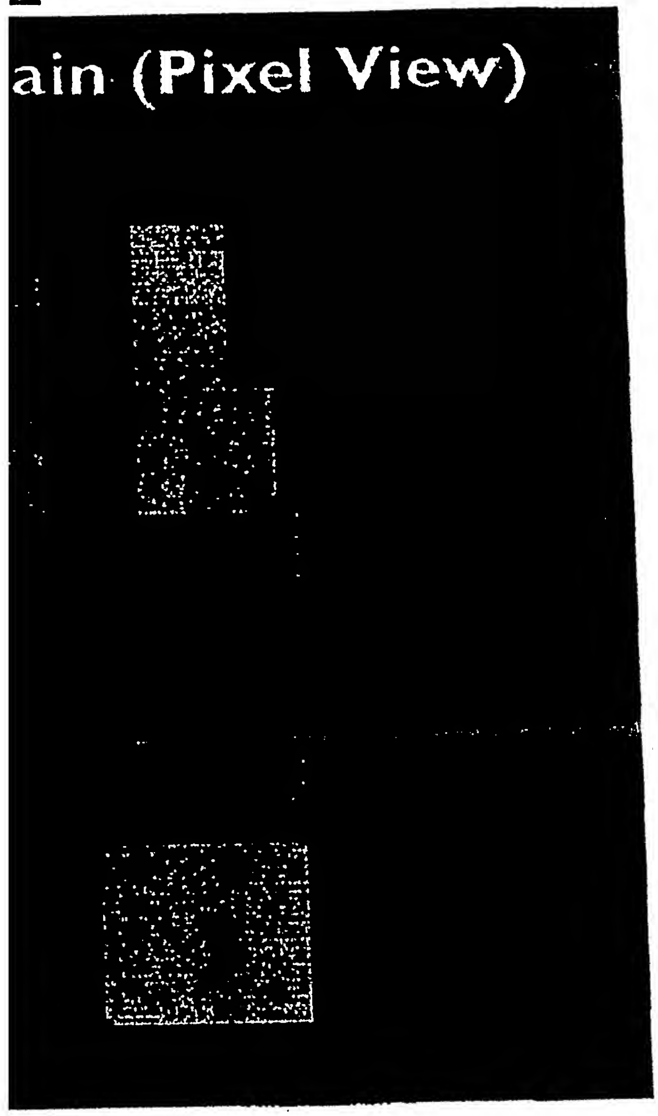

Figure 4

(SOUMEN MUKHERJEE)
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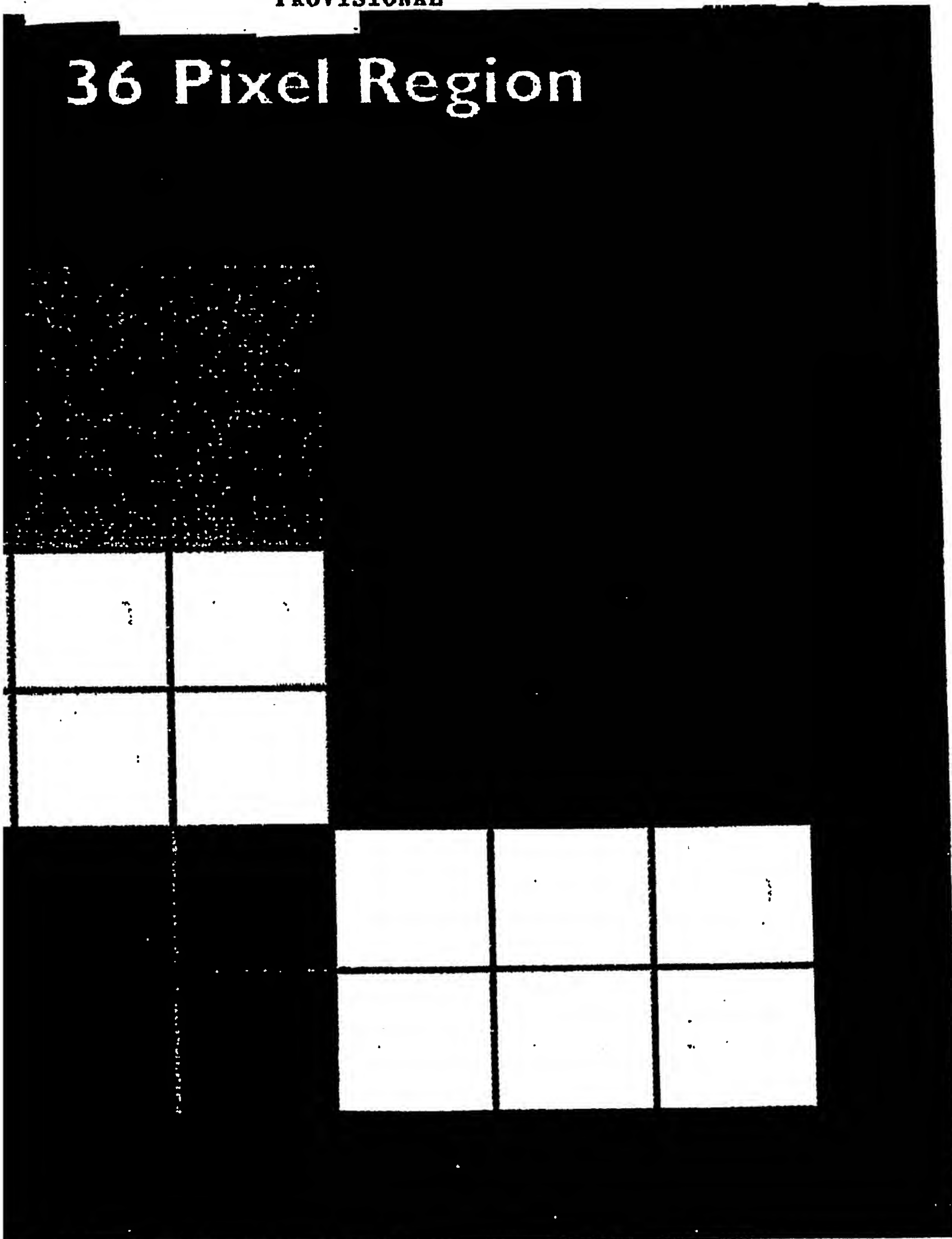

FIGURE 5

(SOUMEN MUKHERJEE)
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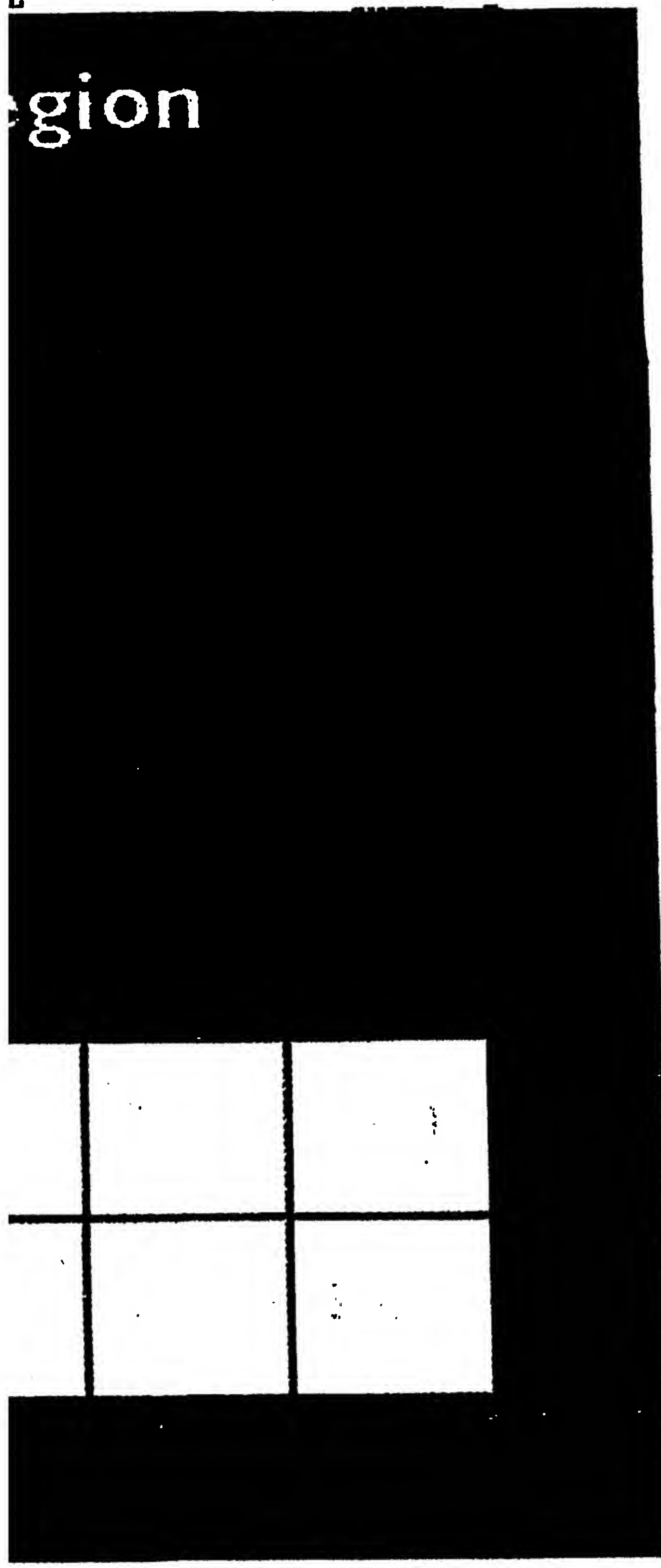

FIGURE 5

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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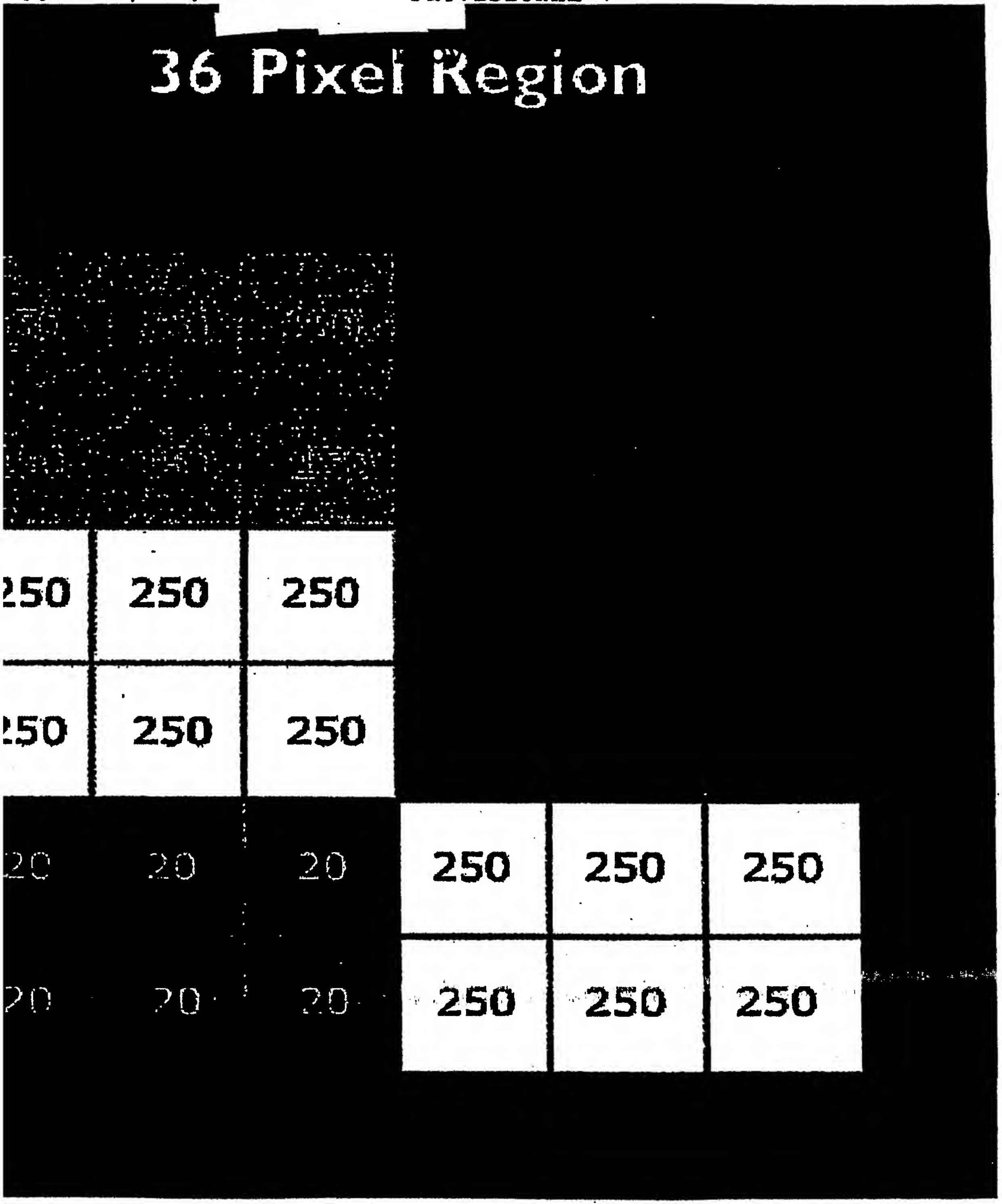

FIGURE 6

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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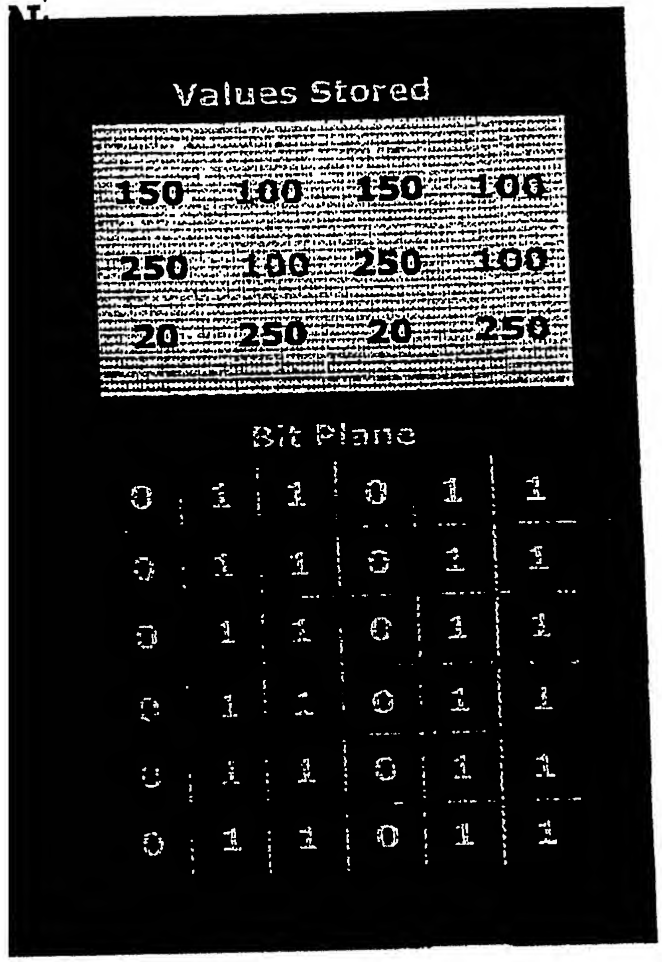

Figure 7

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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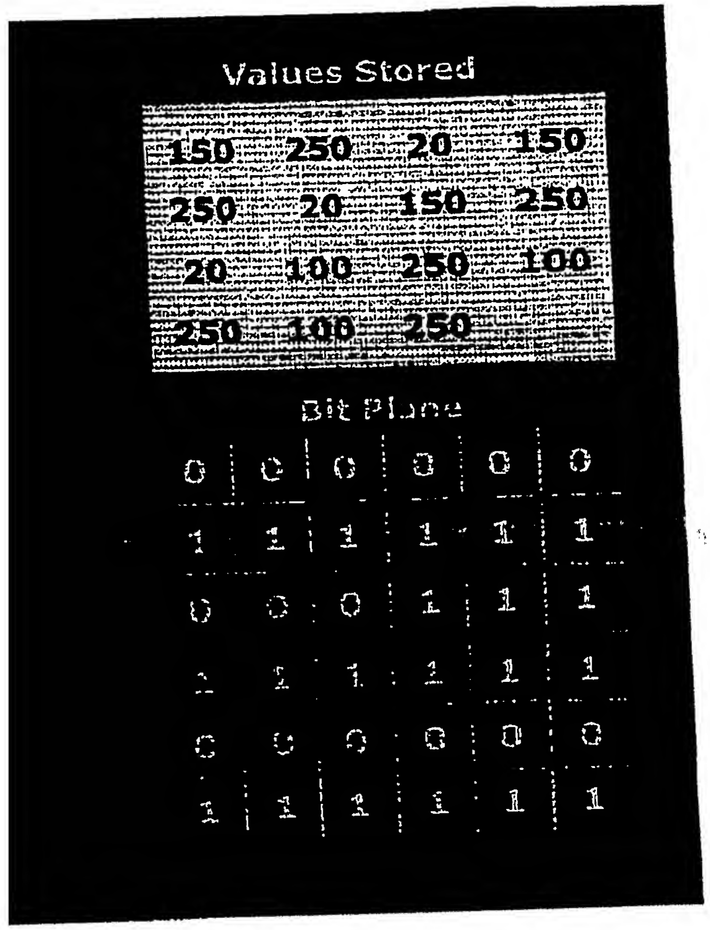

Figure 8

(SOUMEN MUKHERJEE)
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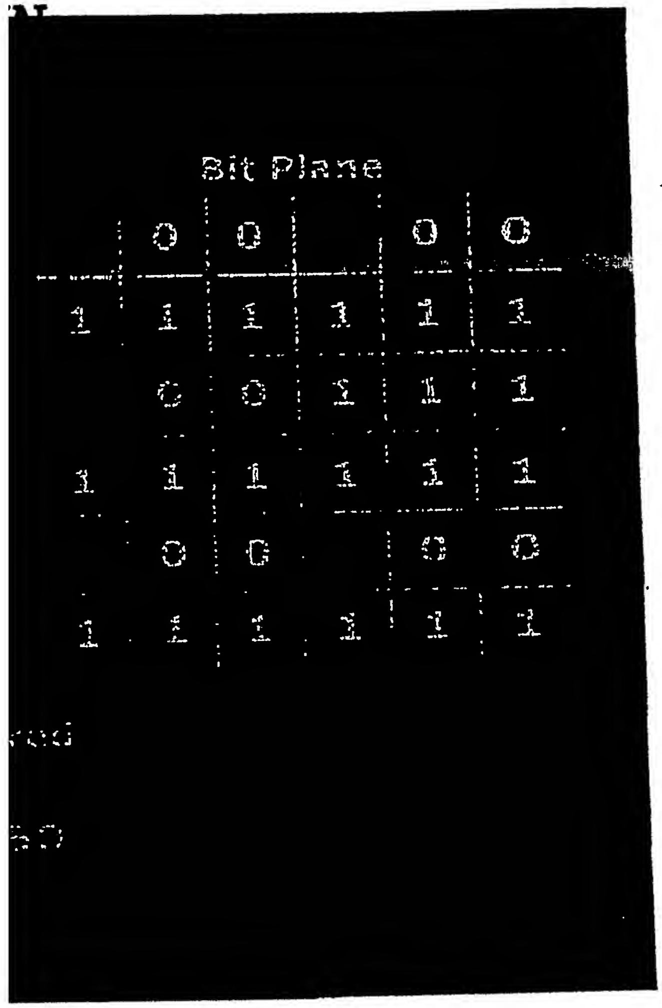

Figure 9

(SOUMEN MUKHERJEE)
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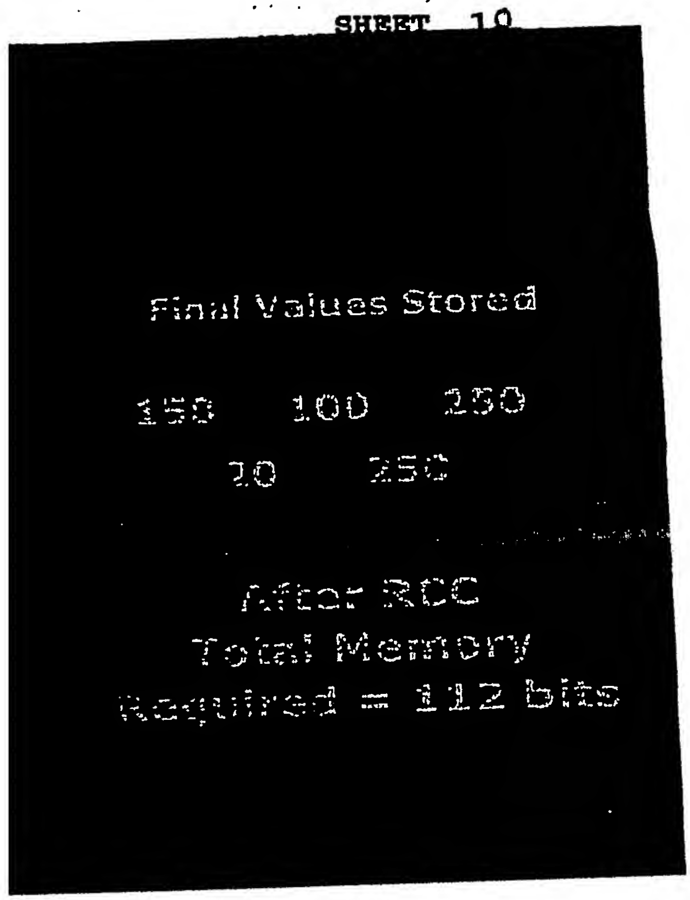

Figure 10

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
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E LIMITED 12 SHEETS

SHEET 11

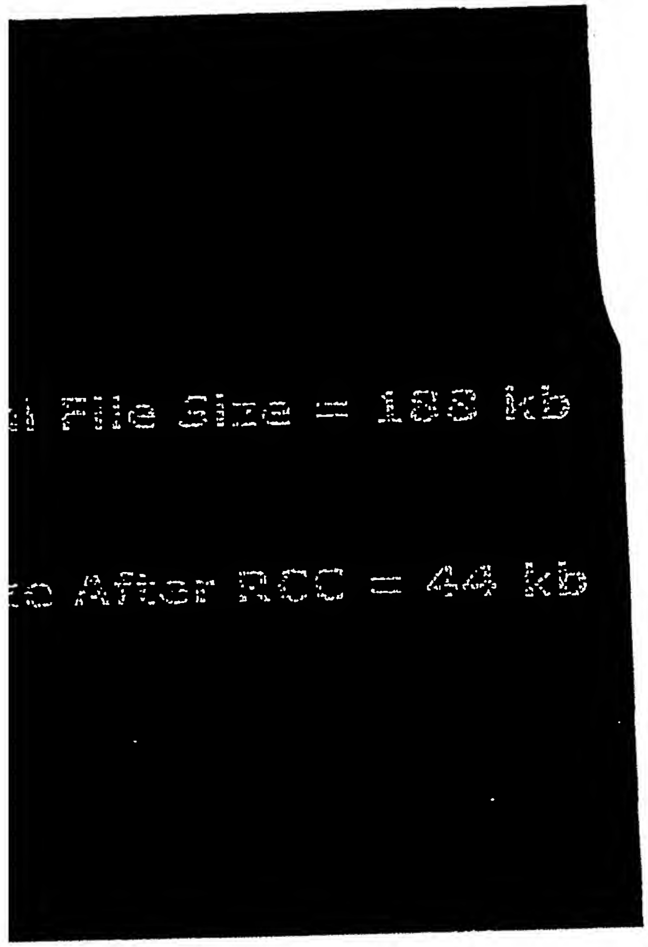

Figure 11

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
APPLICANTS' AGENT

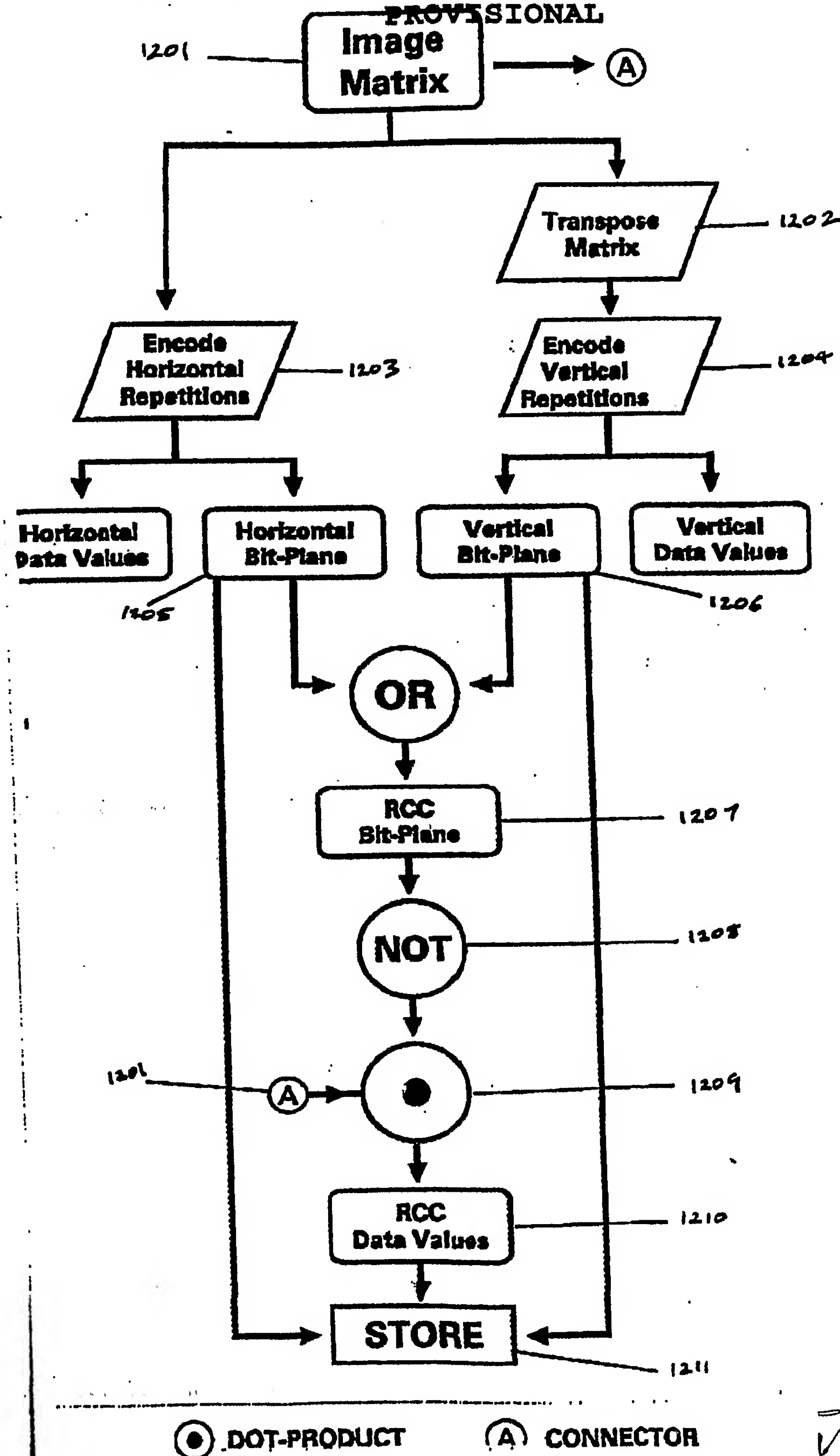

FIGURE 12

(SOUMEN MUKHERJEE)
of D. P. AHUJA & CO.
APPLICANTS' AGENT